

# CHARACTERIZATION OF FLUIDS INVOLVED IN THE GNEISS-CHARNOCKITE TRANSFORMATION IN SOUTHERN KERALA (INDIA)

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Most impressive examples of 'in-situ' charnockitization occur in the Proterozoic crustal segment south of the Achankovil shear belt (Pon Mudi unit (1)), where migmatic garnet-biotite gneisses have been partially converted to coarse-grained charnockite s.str. along a system of conjugate fractures about 550 m.y. ago. To characterise the composition of pore fluids and to understand their role in the process of 'in-situ' charnockite formation, fluid inclusions in spatially related gneisses and charnockites were studied by microthermometry, Raman-Laser-Probe analysis and mass spectrometry (2).  $\delta^{13}\text{C}$  data on graphite (this work and (3)) and fluid inclusions in quartz (4) as well as  $\delta^{18}\text{O}$  whole rock data provided important information on the origin of the fluids.

The fluid inclusion characteristics of the gneisses and associated charnockites are similar and reveal a comparable and complex evolution of the pore fluids. Rare briny inclusions (+ salt) are considered to represent relics of early metamorphic fluids which survived high-grade regional metamorphism and subsequent charnockitization. The common type of fluid inclusions are medium- to low-density carbonic inclusions (Th: +15 to +27 °C; Tm: -60.0 to -56.6 °C;  $\rho$  0.70-0.86 g/cm<sup>3</sup>) which occur in several sets of healed fractures. The microthermometric data indicate partial to complete physical equilibration of these fluids by progressive leakage and repeated reentrapment as a consequence of near-isothermal uplift of the rock complex. The carbonic fluids contain up to 14 mol% of nitrogen but less 1 mol% hydrocarbons (CH<sub>4</sub> and C<sub>2</sub>H<sub>6</sub>). Nitrogen inclusions (Th -152 to -130 °C; up to 16 mol% hydrocarbons, nil carbon dioxide) commonly occur in both the gneisses and charnockites and at several localities predominate. A generation of these fluids by devolatilization of NH<sub>4</sub>-bearing K-feldspar and biotite is likely. The presence of nitrogen and graphite ( $\delta^{13}\text{C}$  -15 to -20 per mil) in the gneisses and charnockites points to the sedimentary nature of the protoliths. Medium-density watery inclusions of low salinity ( $\rho$  0.89 - 0.94 g/cm<sup>3</sup>; < 4 mol% equiv. NaCl) are the texturally latest entrapped metamorphic pore fluids. Where they cross trails of carbonic inclusions, mixed H<sub>2</sub>O-CO<sub>2</sub> inclusions (forming clathrate ices) developed. Bulk fluid analysis by mass spectrometry on quartz concentrates showed the charnockites to be higher in N<sub>2</sub>, CH<sub>4</sub> and H<sub>2</sub>O but lower in H<sub>2</sub> in comparison to the gneisses. CO<sub>2</sub> and Ar have similar abundances in both rock types.

The fluid inclusion characteristics suggest that the composition of metamorphic pore fluids involved in high-grade regional metamorphism and subsequent charnockitization can be modelled

by graphite-fluid equilibria in the C-O-H-N system. Accordingly, the pore fluids in the gneisses and charnockites were internally buffered towards strongly water deficient and reduced compositions. Oxygen fugacities close or lower than defined by the QFM buffer are in accordance with the silicate-opaque mineral assemblages and mineral chemistry data (1,7).

Further evidence for an internal generation and buffering of the pore fluids comes from the  $\delta^{13}\text{C}$  data on graphite and carbonic fluid inclusions: Graphite from typical garnet-biotite-(sill, cord) gneisses exhibit  $\delta^{13}\text{C}$  values between -14‰ and -17‰ (see also (3)) and obviously was derived from the degradation of organic matter (-20‰ to -35‰; data for kerogen). Reported  $\delta^{13}\text{C}$  values for carbon dioxide trapped in the fluid inclusions of comparable gneiss samples vary between -10‰ and -15‰ (4). The difference in the  $\delta^{13}\text{C}$  values of graphite and carbonic fluids (5 to 7‰), in agreement with the experimental fractionation data for the graphite- $\text{CO}_2$  system (5), indicates attainment of isotopic equilibrium near peak metamorphic temperatures (< 700 °C). Graphite and carbonic fluids in coarse-grained massive 'incipient' charnockites show similar  $\delta^{13}\text{C}$  systematics. The graphites are isotopically lighter (-19‰; -22‰) than the carbonic fluids (-7‰ to -15‰; data reported in (4)). Graphite of one charnockite sample, however, has a  $\delta^{13}\text{C}$  value of -12‰, much similar to the values obtained for graphite (-10‰ to -13‰ this work and (3)) from garnet and cordierite-bearing pegmatites which cut across the gneisses but are older than the charnockites. The data could indicate that graphites in these samples crystallised from isotopically heavier carbonic fluids (< -5‰). A meaningful interpretation, however, is not possible unless  $\delta^{13}\text{C}$  data on the associated fluids are available.

A detailed study of oxygen isotopes was carried out on one typical exposure of 'in-situ' charnockitization (Kottavattam). Gneisses and associated charnockites exhibit identical  $\delta^{18}\text{O}$  values of 10.3‰ which are typical of psammo-pelitic metasediments. This findings provide further evidence on the internal nature of carbonic fluids. Influx of carbonic fluids with mantle isotopic signature ( $\delta^{18}\text{O} \sim 8$ ) would have shifted the charnockite  $\delta^{18}\text{O}$  to lower values.

In the light of the fluid inclusion and stable isotope data it thus appears unlikely that charnockitization in southern Kerala was caused by the influx of externally derived carbonic fluids and the concomitant decrease in water activity as suggested by the proponents of the  $\text{CO}_2$ -streaming hypothesis (6). An alternative mechanism has been recently proposed for 'in-situ' charnockitization in southern Kerala (1) and is discussed in an other contribution to the workshop (7).

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